Experimental Development of a Hybrid Solar/Wind System for Energy-saving Management in a Greenhouse

Daisuke YASUTAKE[1], Kiyoshi MIYAUCHI[1], Masaharu KITANO[2], Shinzo YAMANE[1], Yoshinori YAMAMOTO[1], Akiyuki WATANABE[1], Kyosuke YOKOYAMA[3] and Masao HIRAI[2]

[1]Faculty of Agriculture, Kochi University; [2]Faculty of Agriculture,Kyushu University; [3]Watanabe Pipe Co., Ltd.

Abstract: A hybrid solar/wind system for energy-saving management in a greenhouse was newly developed and installed in an agricultural field belonging to the Education and Research Center for Subtropical Field Science, Faculty of Agriculture, Kochi University. This system consists of two main parts: an underground water pipe system and a solar/wind generator system. The pipe system is used for controlling greenhouse air temperature through the exchange of sensible and latent heats between the greenhouse and the water-filled pipe. The solar/wind generation system is used for supplying electrical energy to the pipe system. The performance of the subsystems was assessed by measuring diurnal changes in the rates of heat exchange and generation of electrical energy. During the daytime, both the latent heat and sensible heat of the greenhouse air were stored in the water-filled pipe; during the nighttime, these heats were supplied to the greenhouse. Electrical energy was generated depending on solar radiation and wind speed. These capacities of heat exchange and electrical generation, however, were insufficient for energy-saving management in the greenhouse. From the assessment results, some problems affecting the performance of the system were identified and discussed.

Keywords: Energy-saving management, Greenhouse, Solar/Wind energy, Heat exchange, Electrical generation

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Fig.1

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: AP30 : 19m : 6 m : 4.2m ㈱ Fig. 2 : FA-403 : 127.7MJ h^{-1} 510W ㈱

0.4m ; 2 m : VFC-408P-0.75kW : 0.75kW ㈱ 0.05m Fig.1

: N3-136SH : 0.28kW ㈱ : SWR-300 : 4.96m^2 ㈱

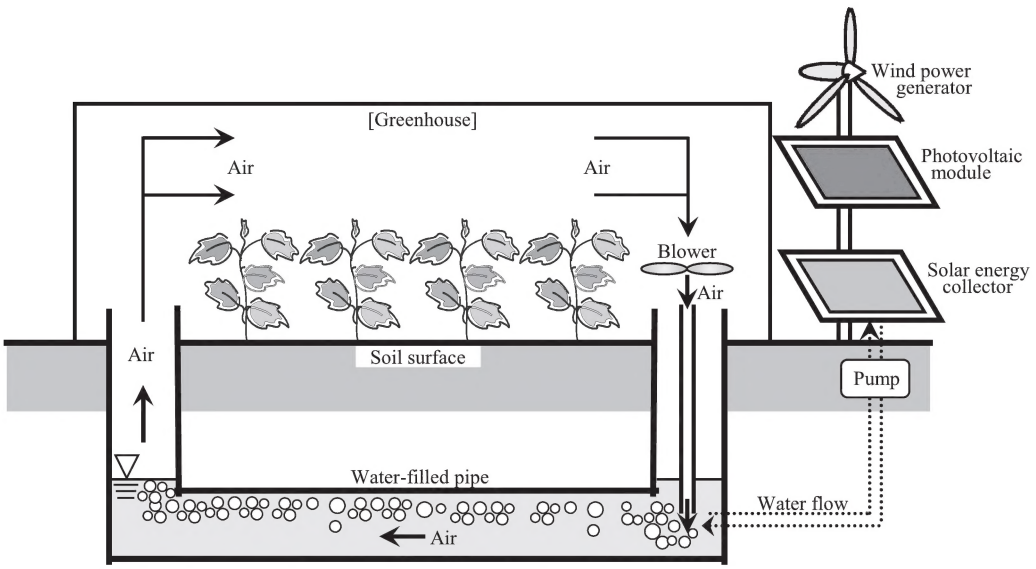

Fig.1 Schematic diagram of the newly developed hybrid solar/wind system for energy-saving management in a greenhouse. This system is composed of two parts: an underground water pipe system and a solar/wind generation system. The pipe system is used for controlling greenhouse air temperature through the exchange of sensible and latent heats between the water-filled pipe and the greenhouse. The solar/wind generation system is used for supplying electrical energy to the pipe system.

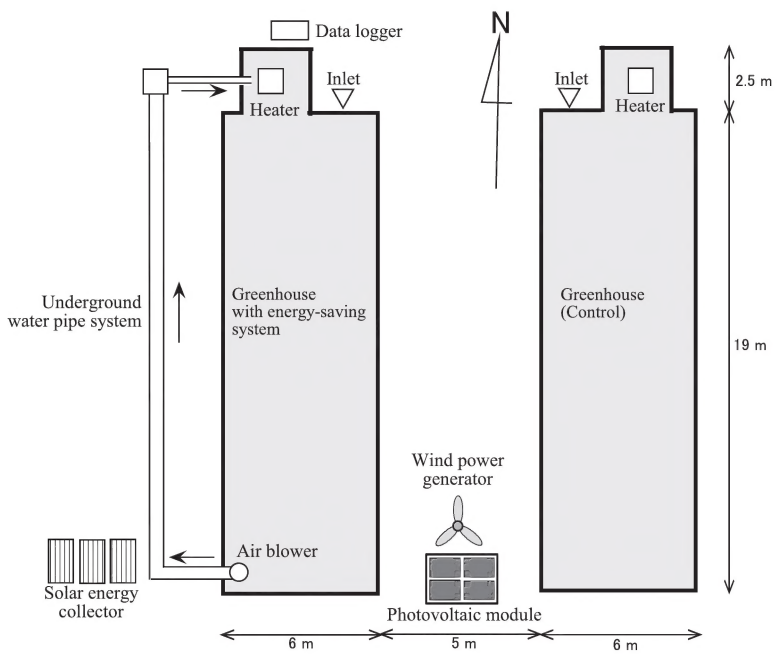

Fig.2 Plane figure of the hybrid solar/wind energy-saving system (underground water pipe system, solar energy collector, photovoltaic module, and wind power generator) installed in the greenhouse.

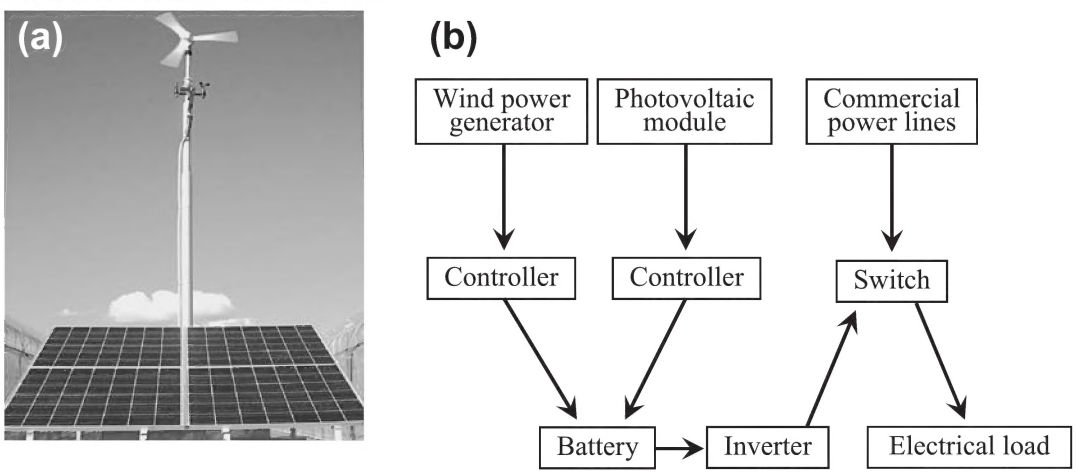

Fig.3 Photograph of the solar/wind generator (a) and block diagram of the electric flow (b).

Table 1 Instruments used for evaluating the energy balance of the greenhouse after the installation of the energy-saving system.

	Variable	Instrument
Outside the greenhouse	Solar radiation Air temperature & humidity Wind speed & direction Soil temperature	CPR-PCM-01, Climatec CVS-HMP45A, VAISALA CYG-3002, Climatec Type T thermocouple
Inside the greenhouse	Net radiation Solar radiation Air temperature & humidity Soil heat flux	CPR-NR-LITE, Climatec CPR-PCM-01, Climatec CVS-HMP45A, VAISALA CPR-PHF-01, Climatec
Underground water pipe system	Air temperature & humidity at the inlet and outlet of the water-filled pipe Water temperature Electric energy consumption of the air blower	RS-12, ESPEC MIC Type T thermocouple NR-1000, KEYENCE
Solar/wind generator	Electric current Electric pressure	NR-TH08, KEYENCE NR-TH08, KEYENCE
Heater	Oil consumption	RN-LSN39, OVAL

$$H = C_p \rho Q (T_{A\,out} - T_{A\,in}) \quad (1)$$

$$\lambda E = \lambda Q (W_{out} - W_{in}) \quad (2)$$

□□□□H□J s^{-1}□□□□□□□□□□$C_p \rho$□J m^{-3} K^{-1}□□□□□□□□□λE□J s^{-1}□□□□□□□□□□ λ□J g^{-1}□□□□□□□□□□□□

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□□□□□□□□□□□□□□□□$T_{A\,in}$□$T_{A\,out}$□□□□□□W_{in}□W_{out}□□□□□□□□□□□T_W□□□□□Fig.5□□□□$T_{A\,in}$□R_S□□□□□3～40℃□□□□□□□□□□□□□□□□□□□$T_{A\,out}$□T_W□□□□□□□□20℃□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□W_{in}□5～25g m^{-3}□□□□□□□□□□□□□□□□□□□□□□□□

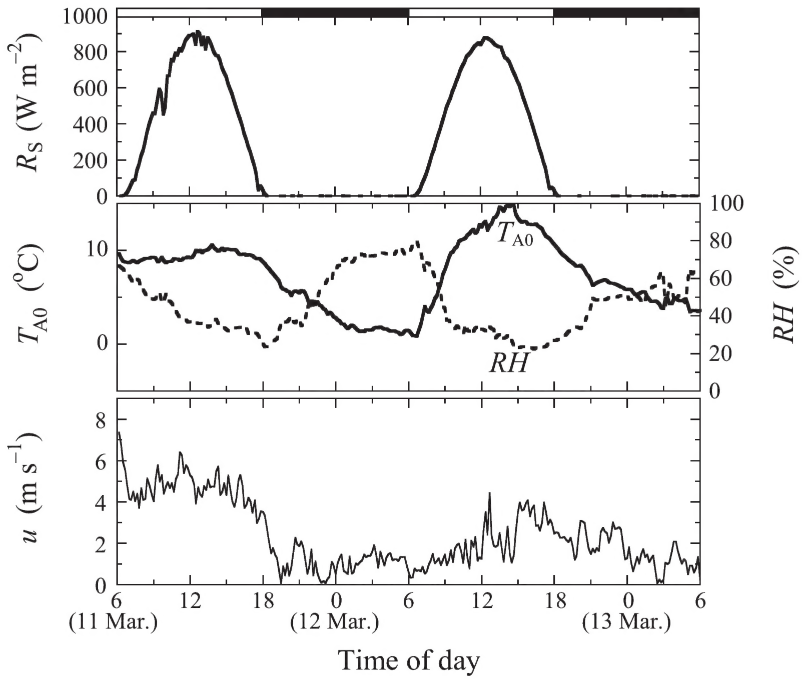

Fig.4 Diurnal changes in solar radiation (R_S), air temperature (T_A), air relative humidity (RH), and wind speed (u) outside the greenhouse during the experimental period (from 0600 on March 11 to 0600 on March 13, 2007). Open and closed bars in the upper part of the R_S graph indicate the daytime and nighttime periods, respectively.

W_{out} □13～15g m^{-3}□1□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□1□□□□2□□ □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□H□□□□□λE□□□□ □□ Fig.6□□□□H□λE□□−300～300J s^{-1}□□□□□□□□□□□□□□□□□□□□□□□□□□ □□□□□□□□□□□□□□□□□□□□□□□□□□□□□[6, 7]□□□□□□□□□□□□□□□□□□□□□□□□□□ □□ □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□1□□□□□□□□□□□□□□□22.5 MJ□□□□□□□□□□□□□□34.6MJ□□□□□□□□□H□λE□□□□□□□□□□□□□□□□□□□□ □□□

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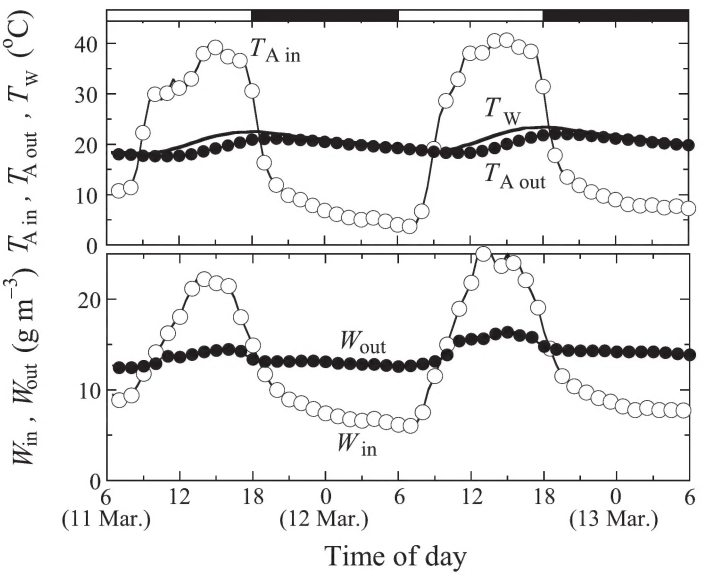

Fig.5 Diurnal changes in air temperatures ($T_{A\,in}$ and $T_{A\,out}$) and water vapor densities (W_{in} and W_{out}) at the inlet and outlet of the water-filled pipe during the experimental period (from 0600 on March 11 to 0600 on March 13, 2007). Water temperature (T_W) in the pipe is also shown. Open and closed bars in the upper part of the temperature graph indicate the daytime and nighttime periods, respectively.

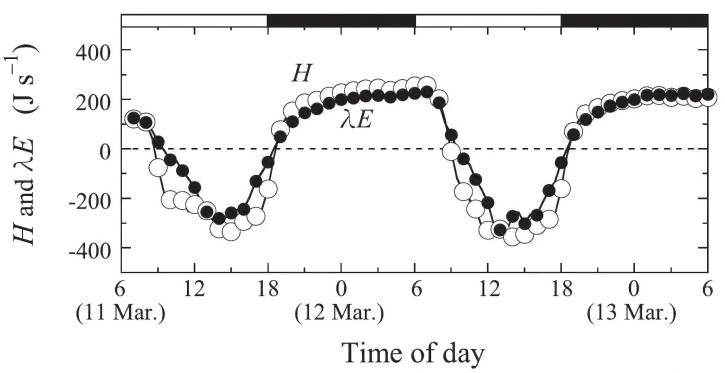

Fig.6 Diurnal changes in rates of exchange of sensible (H) and latent (λE) heats between the underground water pipe system and the greenhouse during the experimental period (from 0600 on March 11 to 0600 on March 13, 2007). Open and closed bars in the upper part of the graph indicate the daytime and nighttime periods, respectively.

Fig.7 R_S 310W m^{-2} Z-500XP 11m s^{-1} [12] 1 ~ 6 m s^{-1} Fig.8 1 1500Wh

900W 200W
1100W 10
1
1 2
6
1650Wh

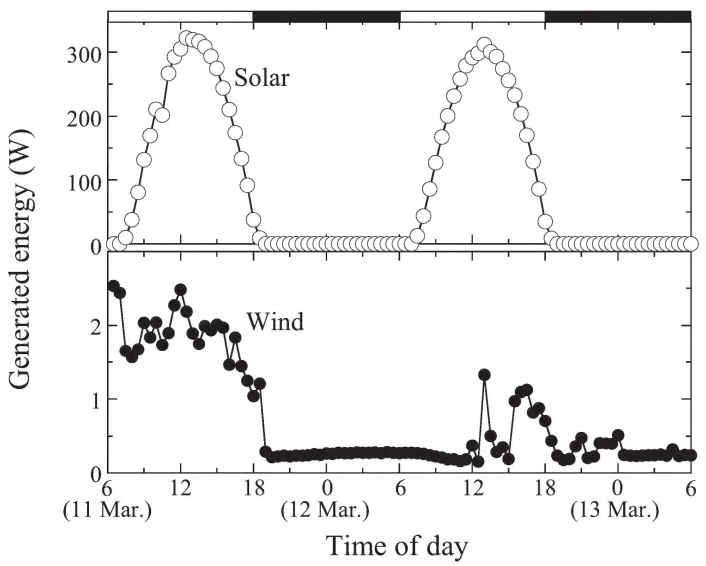

Fig.7 Diurnal changes in electrical energy produced by the solarind generator during the experimental period (from 0600 on March 11 to 0600 on March 13, 2007). Open and closed bars in the upper part of the graph indicate the daytime and nighttime periods, respectively.

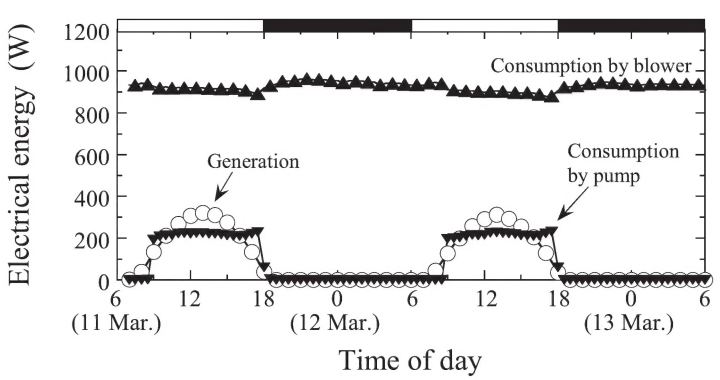

Fig.8 Diurnal changes in electrical generation and electrical consumption by blower and pump during the experimental period (from 0600 on March 11 to 0600 on March 13, 2007). Open and closed bars in the upper part of the graph indicate the daytime and nighttime periods, respectively.

摘 要

%

1 1500Wh 10m s^{-1} 11m s^{-1}

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